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(54) **A method and apparatus for communicating program selections on a multiple channel digital media server having analog output**

(57) A method and apparatus for delivering analog data on demand from a multiple channel digital media server are provided. A number of digital data streams are admitted to a media server. A number of control bits in the form of program packet identifiers are extracted from the admitted digital data streams. One of a number of channels in a converter is allocated as a control channel. A number of control commands are transmitted to the control channel for each of the converter channels in response to user selections, the control commands comprising the extracted program packet identifiers of the digital data streams. The admitted digital data streams are transmitted to the decoding channels of the converter where the converter channels convert the digital data streams to analog data streams in response to the extracted program packet identifiers. The analog data streams may be modulated to produce cable televisions signals or ultrahigh frequency or very high frequency television signals for transmission to clients.

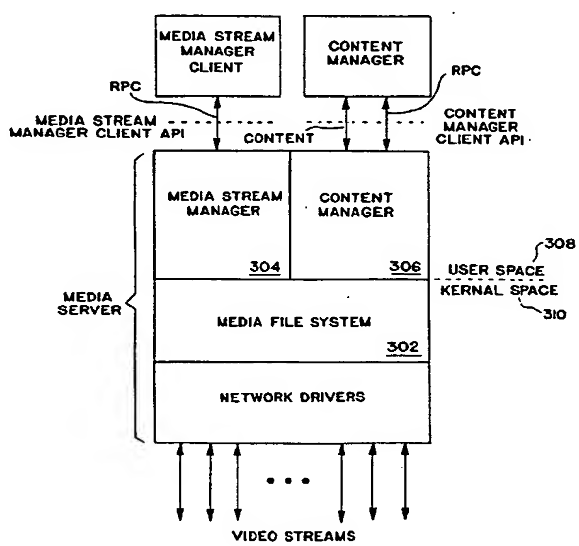

FIG. 5

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er where the converter channels convert the digital data streams to analog data streams in response to the extracted program packet identifiers. The analog data streams may be modulated to produce cable televisions signals or ultrahigh frequency or very high frequency television signals for transmission to clients.

[0010] In one embodiment the media server system comprises a content manager that extracts program packet identifier information from the digital stream when the content is stored on the server. Moreover, the media server system includes a converter control channel to control a number of converter decoding channels. Furthermore, the media server system includes control commands transmitted to the converter control channel in response to user selections, the control commands comprising the extracted program packet identifiers, information from the digital video stream and the converter channel number which will convert the digital stream to analog output. The media server system converts admitted digital data streams to analog video data streams in response to the extracted program packet identifiers.

[0011] It thus becomes possible to decompress and decode the digital video prior to delivery to a client so as to deliver analog video to the client. This allows delivery of video in the existing cable network infrastructure. It also obviates the need for an expensive MPEG decoder in the set-top box at the user client receiver. It also allows for efficient management and control of decoding channel allocation in a multiple channel digital media server.

[0012] As the digital video is decompressed and decoded prior to delivery to a client, the client is required to remotely interact with the media server system using the set-top box to indicate program selections. These client program selections are used to control program delivery. The media server can be designed to select and communicate the appropriate control bits to the MPEG decoder of the media server in order to decode and present to the viewer the selected program materials.

[0013] These and other features, aspects and advantages of the present invention will be apparent from the accompanying drawings and from the detailed description and appended claims which follow, noting that features of the dependent claims may be combined with those of the independent claims as appropriate and in combinations other than those explicitly set out in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The present invention is illustrated by way of example and not limitation in the figures of the accompanying drawings, in which like references indicate similar elements and in which:

[0015] **Figure 1** illustrates the overall architecture for providing analog video in one embodiment of the present invention.

[0016] **Figure 2** illustrates the hardware architecture of one embodiment of the media server of the present invention.

[0017] **Figure 3** illustrates the two different sets of programmatic interfaces of the software of one embodiment of the media server of the present invention.

[0018] **Figure 4** illustrates the Media Stream Manager Client Application Programmer's Interface's (MSMC API's) position in the server architecture.

[0019] **Figure 5** illustrates the relationship between the major software components of the media server of one embodiment of the present invention.

[0020] **Figure 6** illustrates the basic subsystems of the Media File System (MFS) of one embodiment of the present invention.

[0021] **Figure 7** illustrates the media server for providing analog video output in one embodiment of the present invention.

[0022] **Figure 8** illustrates a flowchart for initialization of the Media Channel Selection (MCS) manager in one embodiment of the present invention.

[0023] **Figure 9** illustrates a flowchart for channel allocation in one embodiment of the present invention.

[0024] **Figure 10** illustrates a flowchart for channel deallocation in one embodiment of the present invention.

[0025] **Figure 11** illustrates a flowchart for the actions carried out by the content manager in loading content on the media server of one embodiment of the present invention.

[0026] **Figure 12** illustrates a flowchart for the actions carried out by the media server when the playback of a stream is initiated.

[0027] **Figure 13** illustrates a flowchart for admitting a transport stream into the media server of one embodiment of the present invention.

[0028] **Figure 14** illustrates a flowchart for initializing a data structure of the MFS of one embodiment of the present invention.

[0029] **Figure 15** illustrates a flowchart for the execution of play and stop commands by the MFS of one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0030] A method and apparatus for providing analog output and managing channels on a multiple channel digital media server are provided. In the following description, for purposes of explanation, numerous specific details are set forth. It will be evident, however, to one skilled in the art that the present invention may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form in order to avoid obscuring the description with unnecessary detail.

[0031] **Figure 1** illustrates the overall architecture for providing analog video in one embodiment of the present invention. The Sun™ MediaCenter™ media

signals. These decoders accept, but are not limited to, MPEG-2 video streams. The cable television signals are delivered to a cable transmission system or network. In another embodiment of the media server of the present invention, decoders modulate the analog baseband video and audio signals with a carrier frequency to produce ultrahigh frequency and very high frequency television signals for broadcast.

[0041] An embodiment of the media server of the present invention uses a converter having multiple converting channels, and uses a media server system having multiple converters. The media server manages these multiple converting channels and manages the timely delivery of digital video and audio data to these converting channels. Once the digital video and audio data is converted to analog video and audio data, the media server uses multiple frequencies and multiple paths over a cable network to deliver the analog video and audio data to clients. Therefore, a Media Channel Selection (MCS) manager is implemented in one embodiment of the present invention in order to manage the channels on the multiple channel media server.

[0042] The MCS manager manages a profile of the media server system and controls the allocation and deallocation of channels based on this system profile. The MCS manager establishes a mapping among analog modulation frequencies, SCSI port logical unit numbers, specific decoder cards within converters and specific cables, systems, and networks. Furthermore, the MCS manger allocates and deallocates the aforementioned resources in response to the established mapping and user communications. The MCS manager is implemented as a kernel driver in kernel space as part of the operating system of the media server. The bit pump of the MFS is responsible for timely delivery of video and audio data. Consequently, the MCS manager is optimized to talk to the bit pump directly with regards to allocating and deallocating channels. This direct communication with the bit pump allows for a non-intrusive management of the decoding channels. Implementation of the MCS manager in the kernel prevents leaking of freed channels when a playback is aborted.

[0043] At media server system startup, the MCS manager is initialized. Figure 8 illustrates a flowchart for initialization of the MCS manager in one embodiment of the present invention. At initialization, step 602, a mapping is established among decoder channels, the SCSI ports through which the media server is coupled to the converters, a cable number to which the decoding channels are connected, the output ports of the media server, and the default modulation frequency for the corresponding decoding channels. A mapping is also established among the video program identification, the audio program identification, and the data sampling rate properties of the media server, at step 602.

[0044] Following initialization of the MCS manager, the media server may receive client requests from, for example, a set-top box. When a client communicates to the media server MSM to start playback of a video, the media server must allocate a decoding channel for this client. The MSM client specifies a value that maps to a specific decoder box and, potentially, a specific channel card within that decoder. The bit pump communicates with the MCS manager to allocate a channel. The provisions are also made for the client to pick a particular channel if the client so chooses. The MCS manager allocates a channel and directs the bit pump to deliver video and audio on that channel. The MCS manager also communicates with the decoder box to set the modulation frequency of that channel to that specified by the client or the default modulation frequency as determined at initialization.

[0045] **Figure 9** illustrates a flowchart for channel allocation in one embodiment of the present invention. The MCS manager begins by examining the first decoding channel associated with a specified cable number at step 702. The MCS manager must then decide if the first decoding channel is free at step 704. If the first decoding channel is not free then the MCS manager determines whether there are more ports associated with the specified cable number at step 706. If there are no more ports associated with the specified cable then an error is generated at step 708. If there are more ports associated with the specified cable then the MCS manager picks the next port at step 710 and operation returns to step 704.

[0046] If the first decoding channel is determined to be free at step 704, then the MCS manager determines whether a port with a matching frequency is required at step 712. If a port with a matching frequency is not required, then the port associated with the specified cable number is marked as being in use at step 714, and the first decoding channel is returned to the bit pump at step 716.

[0047] If a port with a matching frequency is determined to be required at step 712, then the MCS manager determines whether the frequency of the port matches the frequency of the decoding channel at step 718. If the frequency of the port does not match the frequency of the decoding channel, then operation continues at step 706 where the MCS manager determines whether there are more ports associated with the specified cable number. If the frequency of the port does match the frequency of the decoding channel, then the port associated with the specified cable number is marked as being in use at step 720, and the first decoding channel is returned to the bit pump at step 722.

[0048] At the end of a video playback, the bit pump communicates with the MCS manager to deallocate the channel previously allocated for the video delivery and makes the channel available for future use. Figure 10 illustrates a flowchart for channel deallocation in one embodiment of the present invention. The MCS manager selects the first cable in the mapping established during the initialization, at step 802. The first port is then selected for this first cable in the mapping, at step 804.

stored on the MFS, at block 1108. The CM also extracts the language identifier field, if present, and stores it in the TOC file. It should be noted that the language identifier field is associated with a PID and some content encoders specify a language identifier in the MPEG bit stream. This language identifier is a three character ASCII string that identifies the language used by the associated elementary stream within the MPEG-2 transport stream.

[0057] The media server, as previously discussed with regards to one embodiment, implements a media stream manager (MSM) which controls the playback of multimedia streams that are stored on the media server. The MSM is logically layered on top of the MFS, and the MSM calls into the MFS to start playback of a stream or to stop a playing stream.

[0058] **Figure 12** illustrates a flowchart for the actions carried out by the media server when the playback of a stream is initiated. The MSM controls the playback of a transport stream by reading the TOC file to retrieve the PIDs associated with a selected playback title, at block 1202. These PIDs include both audio and video PIDs. When a play command is issued for the transport stream, the MSM causes the MFS to start playback of the selected playback title by opening a stream inside the MFS at the time a title is chosen to be played back to some destination. The MSM also takes into account a language identifier field that may be present in the TOC file. Accordingly, the MSM supports a language preference option at startup. When started with this option, the MSM selects the first PID in the selected playback title stream that has a language matching the language preference option.

[0059] Opening a stream inside the MFS involves admitting a transport stream into the media server and making all resource reservations required so that the transport stream can be delivered from the media server at the specified bitrate. Figure 13 illustrates a flowchart for admitting a transport stream into the media server of one embodiment of the present invention. Operation begins at block 1302, at which a video stream scheduler determines whether the current system bandwidth in use plus the bandwidth required to support a new transport stream is less than the bandwidth of the total media server system. If admission of the new transport stream will exceed the total system bandwidth of the media server, then the stream is not admitted, at block 1304. If admission of the new transport stream will not cause the total system bandwidth to be exceeded, then the media server system determines whether a decoding channel is available, at block 1306. The video stream scheduler controls the allocation or reservation of media server bandwidth and allows admission of a new transport stream if the additional bandwidth required does not exceed the media server limit. If a decoding channel is available, the media server then allocates and maintains one channel in an MPEG converter for each transport stream admitted, at block 1308. Thus, the number of transport streams that can be admitted equals the number of decoding channels available. If a decoding channel is not available, then the new transport stream is not admitted, at block 1304.

[0060] Following the opening of a stream inside the MFS, the MFS data structure is initialized. **Figure 14** illustrates a flowchart for initializing a data structure of the MFS of one embodiment of the present invention. As previously discussed, opening a stream involves admitting a transport stream into the media server and thereby making all resource reservations required so that the transport stream can be delivered from the media server at a specified bitrate, at block 1402. Upon opening of a transport stream, the MFS allocates a data structure for each stream within the MFS, at block 1404. There is one data structure for each admitted transport stream. The data structure fields include: state of the stream (playback or stopped); file descriptor associated with the stream; bitrate of the stream; decoding channel address; MFS file handle; and set PID cache handle. Upon initialization of a data structure, at block 1406, the set PID cache flag is reset for that data structure because the PIDs have not been set for the corresponding decoding channel described in the output destination address field of this data structure. The state of the admitted transport stream is also initialized upon initialization of the data structure, along with the other data structure fields.

[0061] Referring again to **Figure 12**, when the playback command is issued, the MSM passes both audio and video PIDs to the MFS. The MFS then initializes an MPEG converter by communicating the audio and video PIDs to the MPEG converter using SCSI driver input/output control commands to the control channel of the MPEG converter, at block 1204. The control commands comprise the extracted program packet identifier information from the digital video stream and the converter channel number which will convert the digital data stream to analog output. This initialization of the MPEG converter is accomplished the first time a play command is issued for a particular transport stream. At block 1206, the MFS, disk scheduler, bitpump, and SCSI drivers stream data to a decoder channel of an MPEG converter. The MPEG converter decodes the selected program material, at block 1208.

[0062] As previously discussed, each MPEG converter of one embodiment of the present invention comprises six decoding channels and one control channel. This single control channel controls all decoding channels of the MPEG converter. There is one central processing unit per MPEG converter that fields all SCSI interrupts, routes transport streams to available decoding channels, and executes all control commands received. Before a decoding channel can decode a selected transport stream, resulting in the playback of a selected program title, the decoding channel PIDs must be initialized for the selected transport stream.

[0063] The MFS bitpump sends MPEG stream data

value used to associate elementary streams in a MPEG transport stream, the at least one of the extracted plurality of program packet identifiers carrying the video and audio elementary streams to be decoded.

3. The method of claim 1 or 2, comprising the step of extracting and storing a plurality of language identifier fields from the plurality of digital data streams.

4. The method of claim 1, 2, or 3, comprising the step of demultiplexing the transmitted digital data stream to provide a program selected by a user.

5. The method of any one of the preceding claims, wherein each of the plurality of digital data streams comprises multiplexed audio and video data, the multiplexed audio and video data comprising a video data stream having at least one audio data stream.

6. The method of any one of the preceding claims, comprising the steps of:

   modulating the at least one of a plurality of analog data streams to produce cable television signals;
   modulating the at least one of a plurality of analog data streams to produce ultrahigh frequency and very high frequency television signals.

7. The method of any one of the preceding claims, comprising the step of converting the at least one of the plurality of digital data streams to the at least one of a plurality of analog data streams using a motion pictures expert group (MPEG) decoder, wherein the plurality of digital data streams are MPEG transport streams.

8. A media server system comprising:

   a content manager operable to extract a plurality of program packet identifiers from a plurality of digital data streams;
   at least one converter control channel; and
   means for transmitting a plurality of control commands comprising the plurality of extracted program packet identifiers to the at least one converter control channel in response to a user selection, and for transmitting at least one of the plurality of digital data streams to at least one of a plurality of converter channels, the at least one of a plurality of converter channels being operable to convert the transmitted at least one of the plurality of digital data streams to an analog video data stream in response to the extracted plurality of program packet identifiers.

9. The media server system of claim 8, comprising means for extracting and storing a plurality of language identifier fields from the plurality of digital data streams.

10. The media server system of claim 8 or 9, comprising means for demultiplexing the transmitted digital data stream to provide a program selected by a user.

11. The media server system of claim 8, 9 or 10, wherein each of the plurality of digital data streams comprises multiplexed audio and video data, the multiplexed audio and video data comprising a video data stream having at least one audio data stream.

12. The media server system of any one of claims 8 to 11, comprising means for modulating the at least one of a plurality of analog data streams to produce cable television signals.

13. The media server system of any one of claims 8 to 12, comprising means for modulating the at least one of a plurality of analog data streams to produce at least one of ultrahigh frequency and very high frequency television signals.

14. The media server system of any one of claims 8 to 13, comprising a motion pictures expert group (MPEG) decoder for converting the at least one of the plurality of digital data streams to the at least one of a plurality of analog data streams, the plurality of digital data streams being MPEG transport streams.

15. A computer readable medium containing executable instructions which, when executed in a processing system, causes the system to perform the steps for delivering analog data to a user in a multiple channel media server comprising the steps of:

   extracting a plurality of program packet identifiers from a plurality of digital data streams;
   transmitting a plurality of control commands for the plurality of converter channels to the control channel in response to a user selection, the plurality of control commands comprising at least one of the extracted plurality of program packet identifiers;
   transmitting at least one of the plurality ofdigital data streams to at least one channel of the plurality of converter channels, the at least one channel of the plurality of converter channels converting the transmitted at least one of the plurality of digital data streams to at least one of a plurality of analog data streams in response to the at least one of the extracted plurality of program packet identifiers.

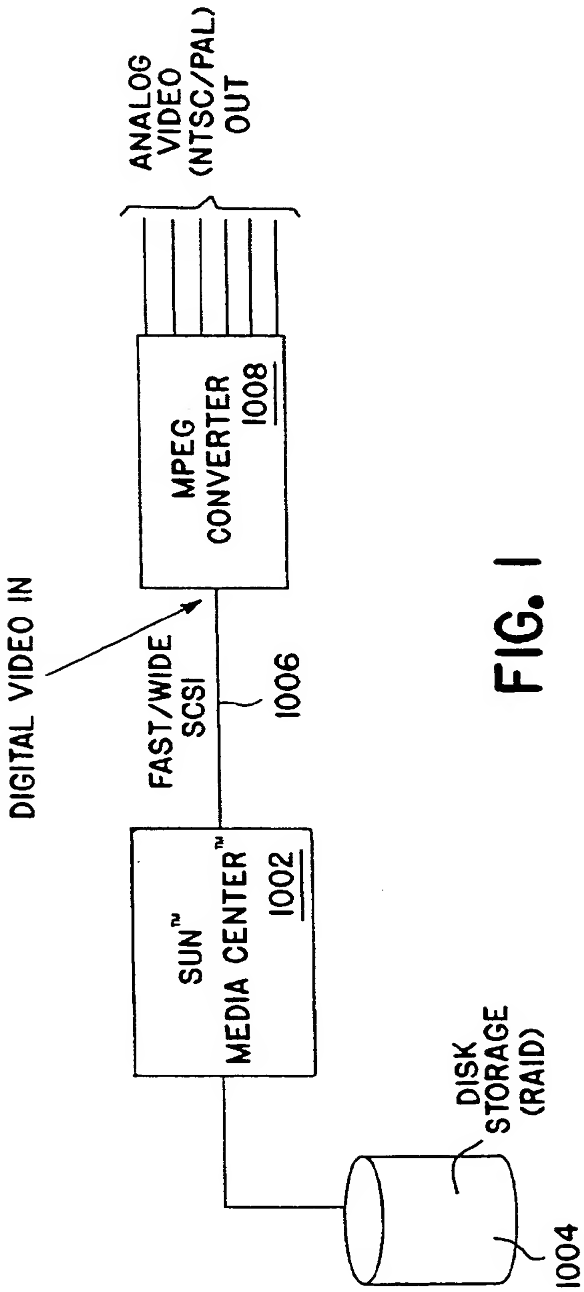
ANALOG VIDEO (NTSC/PAL) OUT
MPEG CONVERTER
1008
DIGITAL VIDEO IN
FAST/WIDE SCSI
1006
SUN™ MEDIA CENTER™
1002
DISK STORAGE (RAID)
1004

FIG. 1

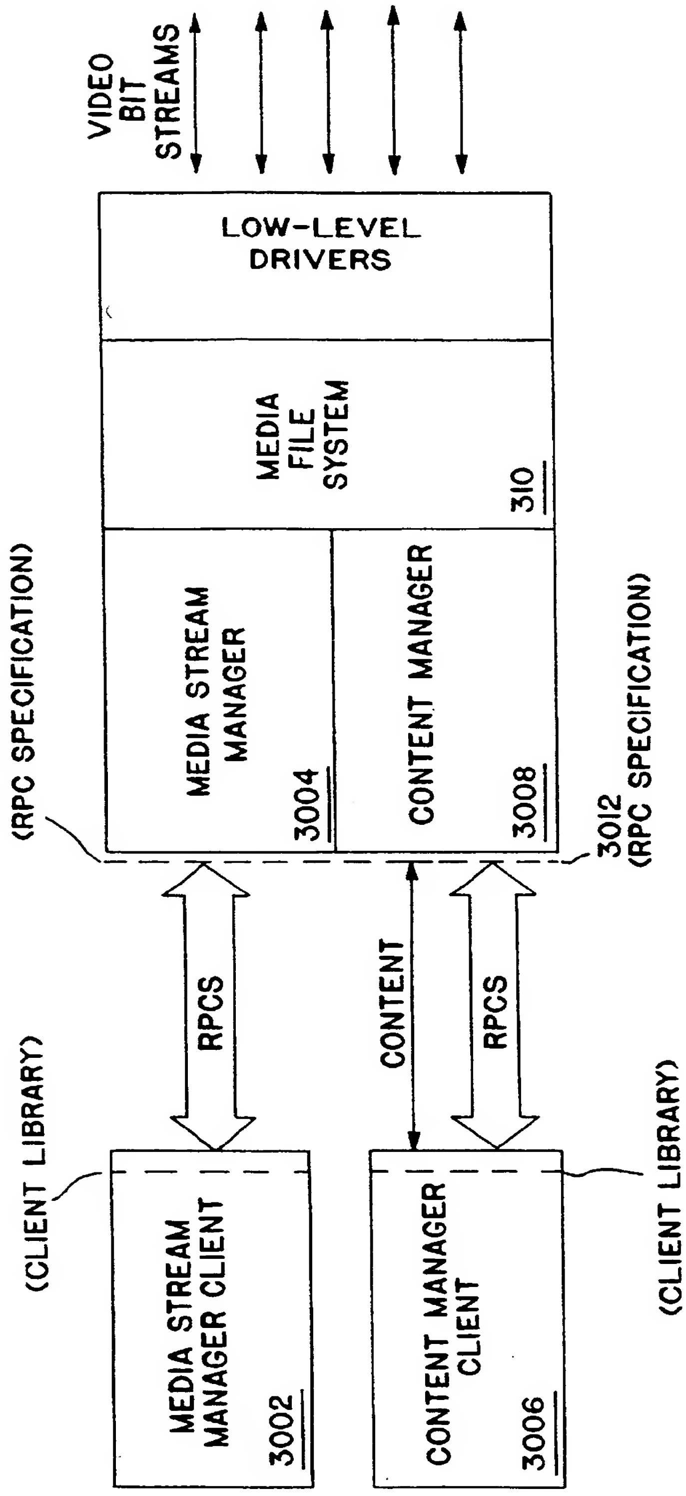
VIDEO BIT STREAMS
LOW-LEVEL DRIVERS
MEDIA FILE SYSTEM
310
MEDIA STREAM MANAGER
3004
CONTENT MANAGER
3008
(RPC SPECIFICATION)
3012 (RPC SPECIFICATION)
RPCS
CONTENT
RPCS
(CLIENT LIBRARY)
(CLIENT LIBRARY)
MEDIA STREAM MANAGER CLIENT
3002
CONTENT MANAGER CLIENT
3006

FIG. 3

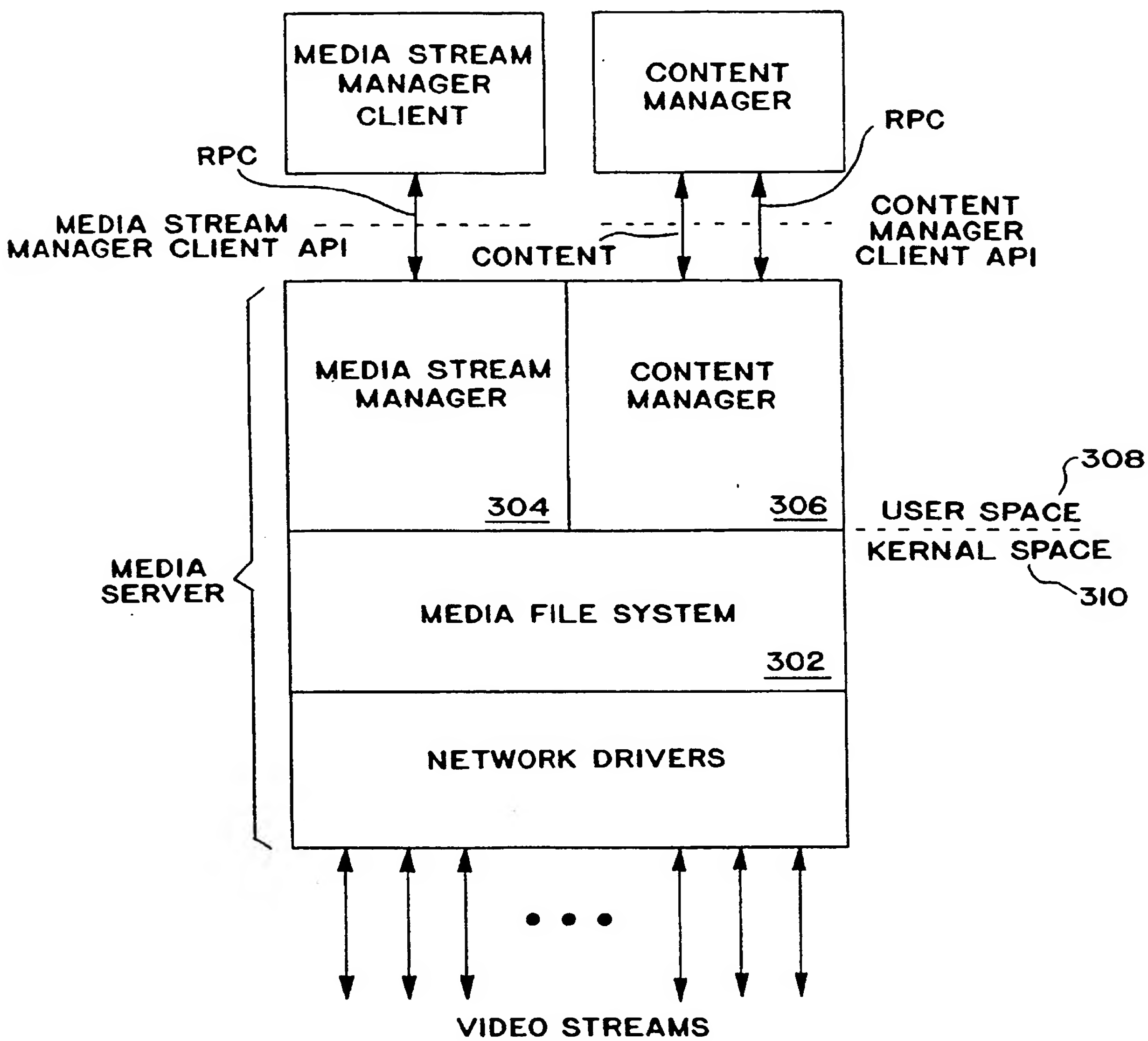
MEDIA STREAM MANAGER CLIENT
CONTENT MANAGER
RPC
RPC
MEDIA STREAM MANAGER CLIENT API
CONTENT
CONTENT MANAGER CLIENT API
MEDIA STREAM MANAGER
304
CONTENT MANAGER
306
308
USER SPACE
KERNAL SPACE
310
MEDIA SERVER
MEDIA FILE SYSTEM
302
NETWORK DRIVERS
VIDEO STREAMS

FIG. 5

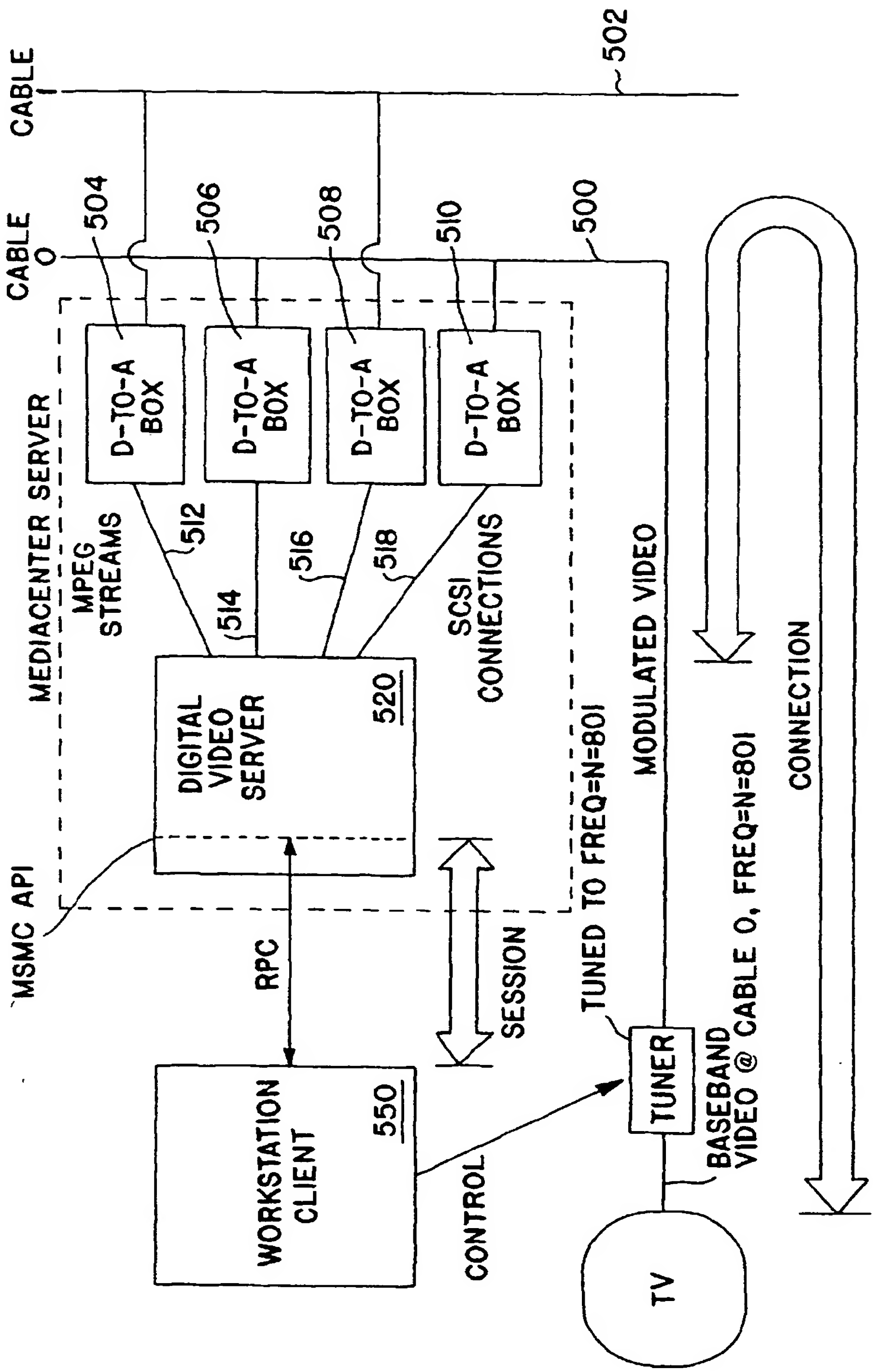
CABLE 1
502
CABLE 0
504
506
508
510
500
MEDIACENTER SERVER
D-TO-A BOX
D-TO-A BOX
D-TO-A BOX
D-TO-A BOX
MPEG STREAMS
512
514
516
518
SCSI CONNECTIONS
DIGITAL VIDEO SERVER
520
MSMC API
RPC
SESSION
TUNED TO FREQ=N=801
MODULATED VIDEO
TUNER
WORKSTATION CLIENT
550
CONTROL
BASEBAND VIDEO @ CABLE 0, FREQ=N=801
CONNECTION
TV

FIG. 7

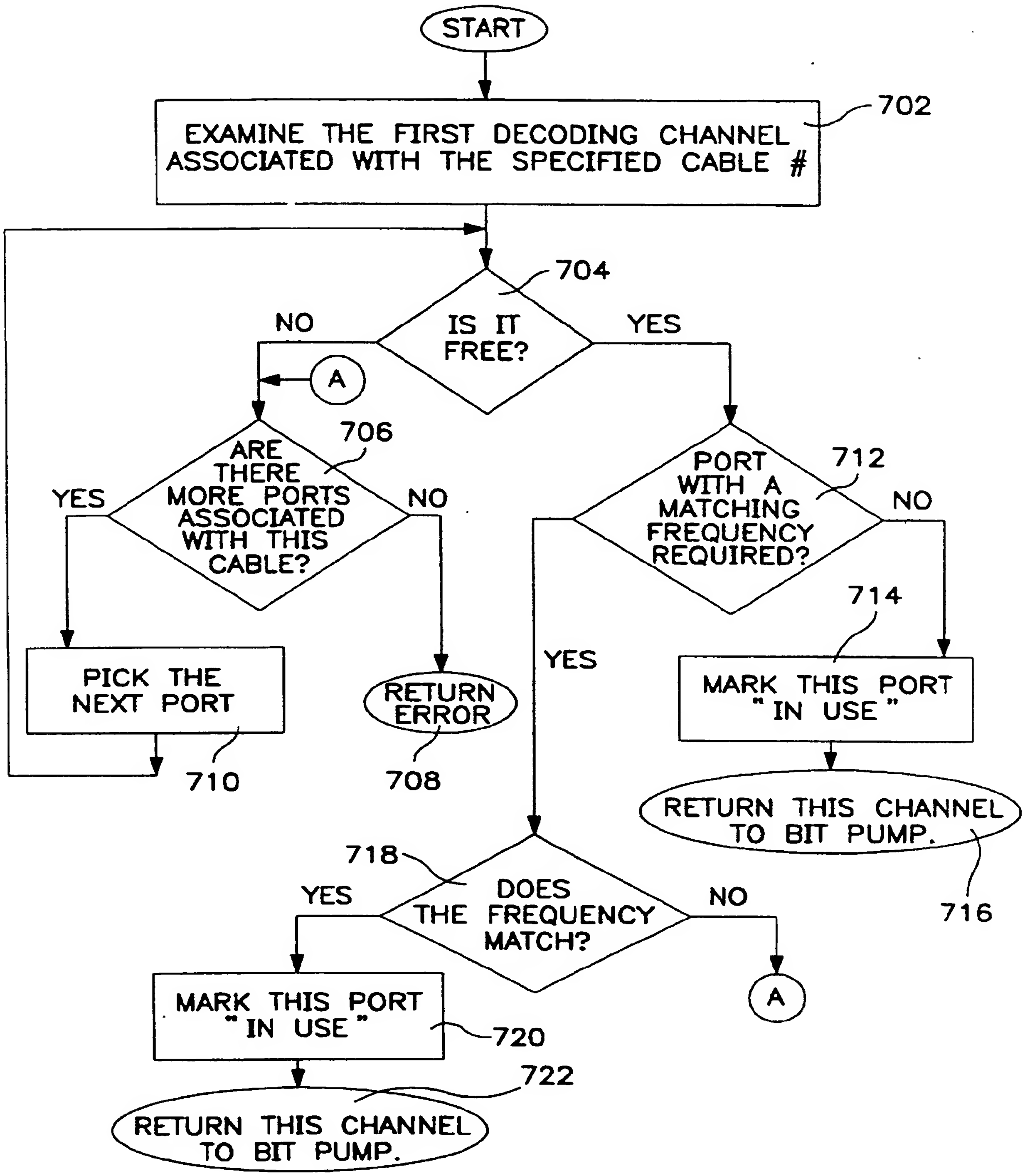
START
EXAMINE THE FIRST DECODING CHANNEL ASSOCIATED WITH THE SPECIFIED CABLE #
702
704
IS IT FREE?
NO
YES
A
706
ARE THERE MORE PORTS ASSOCIATED WITH THIS CABLE?
YES
NO
712
PORT WITH A MATCHING FREQUENCY REQUIRED?
NO
YES
PICK THE NEXT PORT
710
RETURN ERROR
708
714
MARK THIS PORT " IN USE "
RETURN THIS CHANNEL TO BIT PUMP.
716
718
DOES THE FREQUENCY MATCH?
YES
NO
A
MARK THIS PORT " IN USE "
720
722
RETURN THIS CHANNEL TO BIT PUMP.

FIG. 9

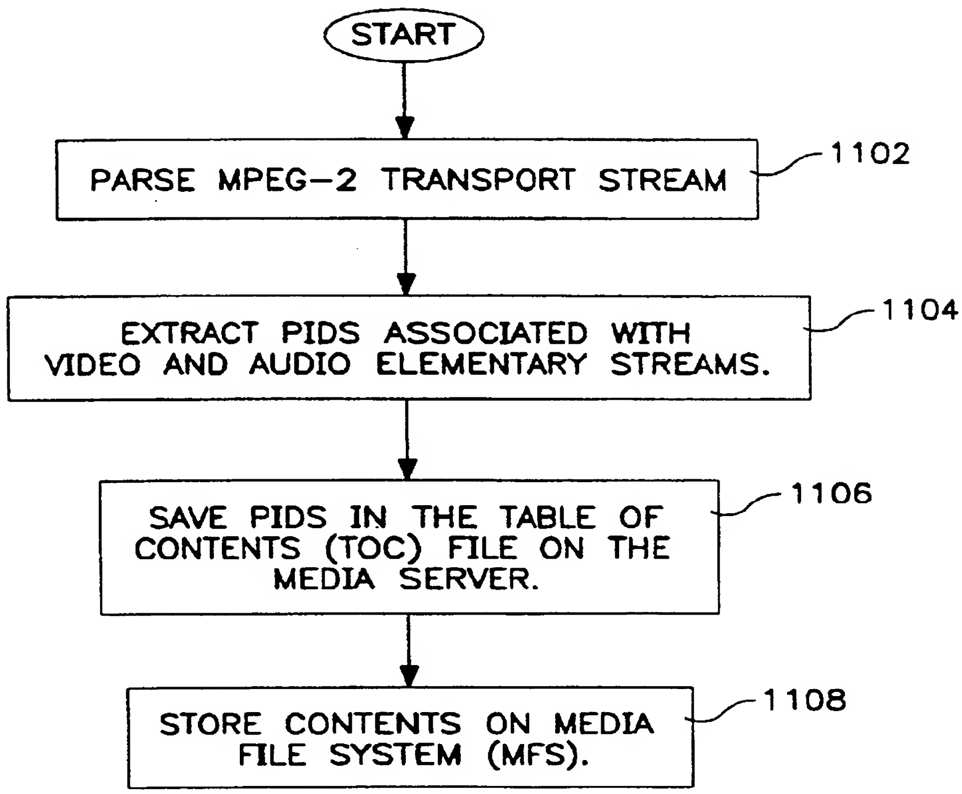
START
PARSE MPEG-2 TRANSPORT STREAM
1102
EXTRACT PIDS ASSOCIATED WITH VIDEO AND AUDIO ELEMENTARY STREAMS.
1104
SAVE PIDS IN THE TABLE OF CONTENTS (TOC) FILE ON THE MEDIA SERVER.
1106
STORE CONTENTS ON MEDIA FILE SYSTEM (MFS).
1108

FIG. 11

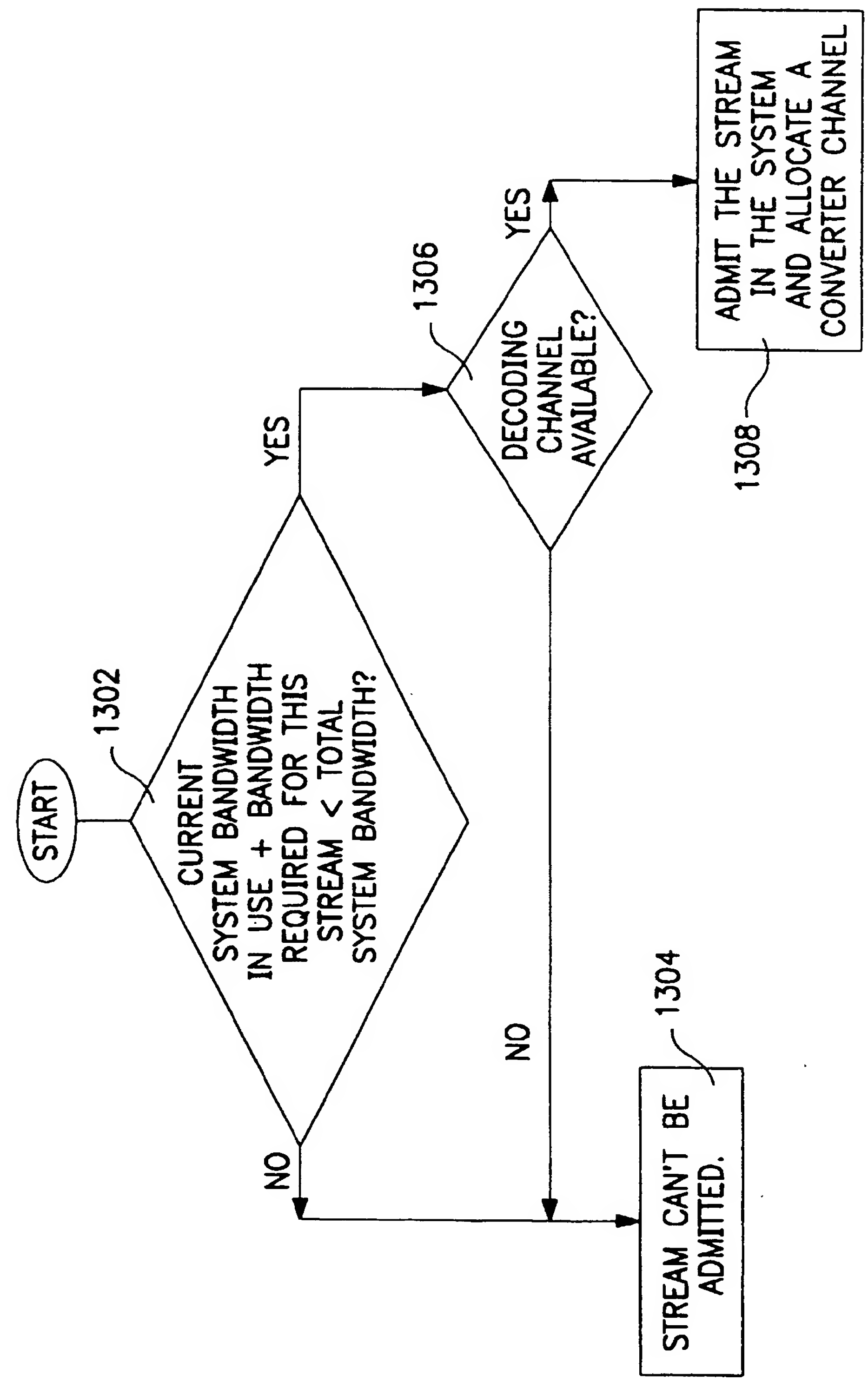
START
1302
CURRENT SYSTEM BANDWIDTH IN USE + BANDWIDTH REQUIRED FOR THIS STREAM < TOTAL SYSTEM BANDWIDTH?
YES
NO
1304
STREAM CAN'T BE ADMITTED.
1306
DECODING CHANNEL AVAILABLE?
YES
NO
1308
ADMIT THE STREAM IN THE SYSTEM AND ALLOCATE A CONVERTER CHANNEL

FIG. 13

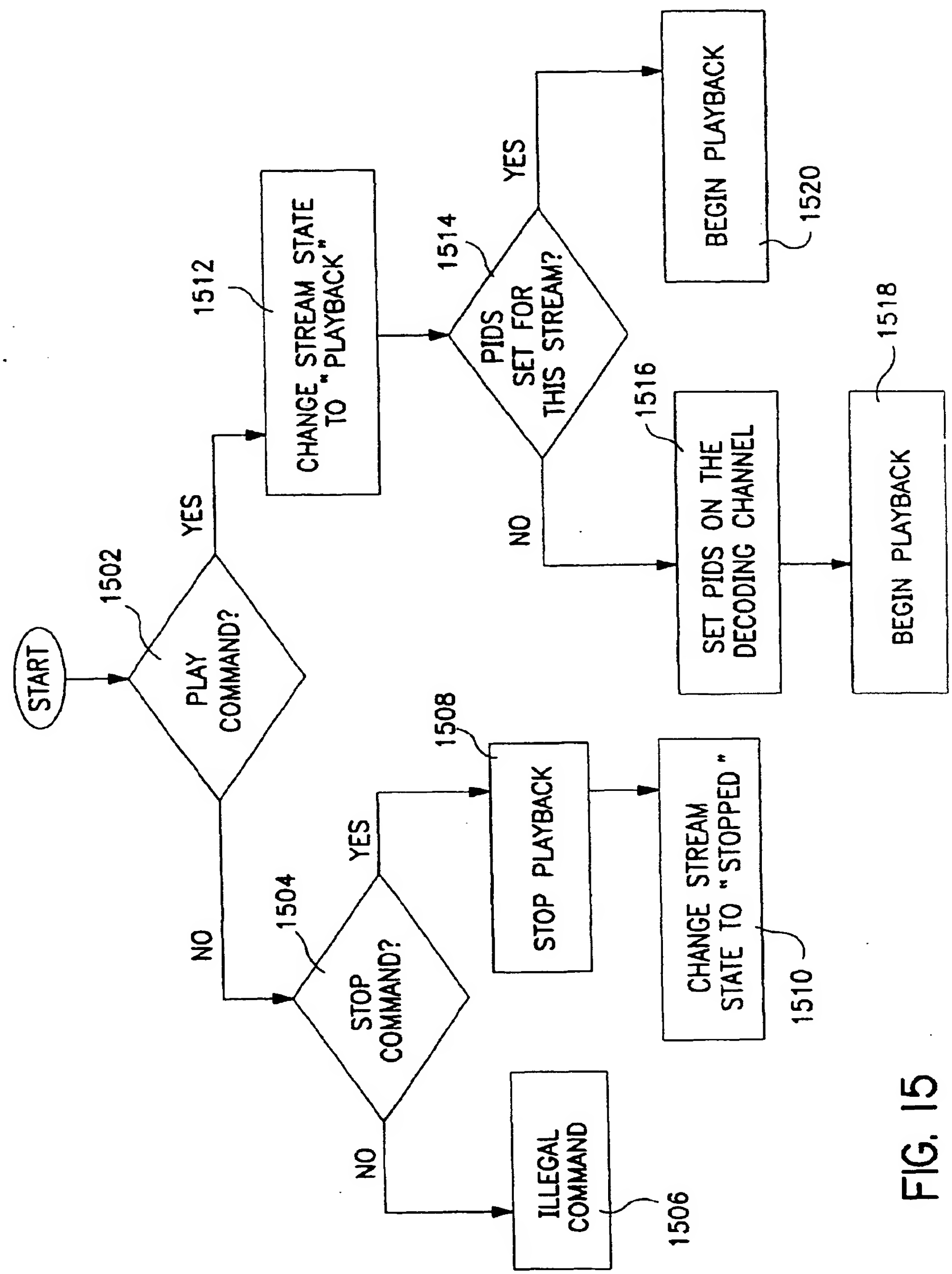
START
PLAY COMMAND?
1502
YES
NO
CHANGE STREAM STATE TO "PLAYBACK"
1512
PIDS SET FOR THIS STREAM?
1514
YES
NO
BEGIN PLAYBACK
1520
SET PIDS ON THE DECODING CHANNEL
1516
BEGIN PLAYBACK
1518
STOP COMMAND?
1504
YES
NO
STOP PLAYBACK
1508
CHANGE STREAM STATE TO "STOPPED"
1510
ILLEGAL COMMAND
1506

FIG. 15